Pearling: Stroke Segmentation with Crusted Pearl Strings[1]

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Abstract—We introduce a novel segmentation technique, called *Pearling*, for the semi-automatic extraction of idealized models of networks of strokes (variable width curves) in images. These networks may for example represent roads in an aerial photograph, vessels in a medical scan, or strokes in a drawing. The operator seeds the process by selecting representative areas of good (stroke interior) and bad colors. Then, the operator may either provide a rough trace through a particular path in the stroke graph or simply pick a starting point (seed) on a stroke and a direction of growth. Pearling computes in realtime the centerlines of the strokes, the bifurcations, and the thickness function along each stroke, hence producing a purified medial axis transform of a desired portion of the stroke graph. No prior segmentation or thresholding is required. Simple gestures may be used to trim or extend the selection or to add branches. The realtime performance and reliability of Pearling results from a novel disk-sampling approach, which traces the strokes by optimizing the positions and radii of a discrete series of disks (pearls) along the stroke. A continuous model is defined through subdivision. By design, the idealized pearl string model is slightly wider than necessary to ensure that it contains the stroke boundary. A narrower core model that fits inside the stroke is computed simultaneously. The difference between the pearl string and its core contains the boundary of the stroke and may be used to capture, compress, visualize, or analyze the raw image data along the stroke boundary.

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1. INTRODUCTION

In this paper, we present *Pearling*, for the extraction and modeling of stroke-like structures in images. This work is motivated by the need for semi-automatic segmentation tools, particularly in the analysis of medical images. Indeed, every year millions of medical images are taken, many of which are used lo support clinical applications involving diagnosis (e.g., stenosis, aneurysm, etc.) surgical planning, anatomic modeling and simulation, and treatment verification. These applications either benefit from, or are required to have, a geometric model of the important structures (blood vessel, airway, etc.) being studied. Segmentation of stroke-like structures such as blood vessels is a fundamental problem in medical image processing, and arises in other contexts including industrial applications as well as aerial/satellite image analysis.

With manual segmentation techniques, it is possible to obtain highly accurate results. However, these methods typically require an excessive amount of tedious labor to be practical in a clinical workflow. While fully automatic segmentation methods can be desirable in these applications, given the poor contrast, noise, and clutter that is common to medical images, it is often difficult for fully automatic segmentation methods to yield robust results. Furthermore, often one is interested in extracting only a subset, for example a specific path through a branching network of stroke-like structures. Therefore, there is a salient need for interactive segmentation methods that are *mostly* automatic, but do accept input from the operator to guide the segmentation in a particular direction, quickly correct for errant segmentations, and add branches to an existing segmentation result. Crucial to such a semi-automatic segmentation method is computational efficiency, so that the operator will not have to wait for segmentation results while interacting with the data. Furthermore, to support further analysis or close-up visualization it may be important to identify the portion of the image (crust) that surrounds the stroke boundary.

1.1. Related Work

Given its clinical importance, the problem of vessel segmentation has received a fair amount of attention in the literature. Kirbas and Quek [1] present a recent survey that provide a recent survey of techniques for vessel segmentation. They conclude that there is no single vessel segmentation approach that is robust, automatic, and fast, and that successfully extracts the vasculature across all imaging modalities and different anatomic regions. Following their conclusion, we step away from total automation and instead focus in interactive segmentation, providing an efficient system for an operator to quickly extract the region and branches of interest.

Other recent vessel segmentation approaches in the medical imaging literature include [2], who model vessel segments using superellipsoids, [3], who implement

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